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The Efficacy of State of the Art Overground Gait Rehabilitation Robotics: A Bird's Eye View

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Abstract

To date, rehabilitation robotics has come a long way effectively aiding the rehabilitation process of the patients suffering from paraplegia or hemiplegia due to spinal cord injury (SCI) or stroke respectively, through partial or even full functional recovery of the affected limb. The increased therapeutic outcome primarily results from a combination of increased patient independence and as well as reduced physical burden on the therapist. Especially for the case of gait rehabilitation following SCI or stroke, the rehab robots have the potential to significantly increase the independence of the patient during the rehabilitation process without the patient's safety being compromised. An intensive gait-oriented rehabilitation therapy is often effective irrespective of the type of rehabilitation paradigm. However, eventually overground gait training, in comparison with body-weight supported treadmill training (BWSTT), has the potential of higher therapeutic outcome due its associated biomechanics being very close to that of the natural gait. Recognizing the apparent superiority of the overground gait training paradigms, a through literature survey on all the major overground robotic gait rehabilitation approaches was carried out and is presented in this paper. The survey includes an in-depth comparative study amongst these robotic approaches in terms of gait rehabilitation efficacy.

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1. Introduction

Spinal cord injuries (SCIs), stroke and even cardiovascular disease (CVD) often lead to gait disability leading to the condition of paraplegia or hemiplegia [1]. Such disability often causes distress to the daily life of the affected person and his or her family in various ways. Consequently, patients with disability may face with difficulties in pursuing their normal life. Therefore, it is vital for them to go through rehabilitation training at a stage as early as possible, as there is always a chance that they may regain the ability of some functional movements and enhance the quality of their life [2].

In recent years, there has been an increasing amount of literature in the field of rehabilitation robotics. There are many types of rehabilitation robots that have been developed just relatively recently, of which, the gait rehabilitation robots constitutes a large portion. The gait rehabilitation robots can be divided into two categories, viz. body-weight supported treadmill training (BWSTT) and overground gait training. BWSTT is usually an obvious choice for the patients with acute conditions due to the severity of the condition demanding stringent requirement for safety, which is usually relatively easily ensured in BWSTT. After a while, an overground training is needed in order to have a better walking education. Subjects with sub-acute motor incomplete SCI reached a higher level of independent walking after overground training, compared to BSWTT. Furthermore, BWSTT is said to be non-ecological training as patients cannot move freely and will only have to perform their gait re-education at a controlled speed of the treadmill. Besides, patients are not be able to walk independently as BWSTT is usually delivers fixed gate pattern.

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BWSTT does not cater for individual patient's gait pattern and requires as all of them undergo the same gait training [3]. These drawbacks has led to the alternative path of gait re-education, i.e. overground training.

A brief survey of the existing robotic overground gait training solutions is conducted in this work. The primary objective of the survey is to present the reader with a comparative evaluation of the various robotic solutions in terms of therapeutic outcome and other relevant features. Depending on the way the patient is secured within the device, the overground rehabilitation robots are first classified into two major categories, viz. with BWS and with exoskeletal support. An in-depth comparative evaluation amongst the existing approaches is discussed in the Discussions Section followed by Concluding Remarks.

2. Robotic Overground Gait Training Modalities

The overground gait training robots are, in essence, mobile robot platforms specially designed and equipped to facilitate the gait training. Patients are usually secured with body-weight support system (BWS), attached firmly to the robot frame. The approach results in a much reduction in the physical constraints on the patients, thereby allowing them to move freely by having the mobile robot simply following them. The approach has the potential to stimulate the re-learning of the functional motor pattern of overground walking in an optimal manner while increasing patient's motivation, which constitutes a crucial element in the subject's re-education [4]. With a view to combine benefits of the orthotic support (e.g. increased safety, reduced joint degrees-of-freedom etc.), that might be useful for certain patient group, more complex exoskeletons have also been used in conjunction with the over-ground gait training.

2.1. Overground Gait Training Robots With Body-Weight Support

The overground gait training robots with BWS constitutes major part of the recent development in rehabilitation robotics. In this approach, the patient's safety is fully ensured using an overhead harness, i.e. the BWS [5]. An appraisal of the recent developments within this modality of the rehab robots is carried out in this subsection.

2.1.1. SoloWalk

The SoloWalk [6] (Figure 1) is one of the BWS rehabilitation robots that is aimed towards helping individuals suffering from spastic quadriplegia to cerebral palsy (CP). SoloWalk is powered by geared DC motors for its omnidirectional wheels while a harness system, attached to a pair of underarm bars, for the BWS is designed to lift the patients and prevent them from falling. Between the frame and the harness is a force sensor that measures interaction force generated by the patient's intention of movement. The torso harness is design to reduce the pressure occurring at the shoulder while the patient is suspended from the device.

The SoloWalk is supposed to largely reduce the therapist's physical workload. Users are supposed to be able to walk freely with the assistance of the device while the robot simply follows the patient's motion. Therapists monitor the therapy and a remote control is used to initiate patient's movement or therapist can also follows patient desired walking path.

Figure 1: SoloWalk [5]

2.1.2. Andago

The assistive rehabilitation robot called Andago (Figure 2) has recently been commercialized by a Swiss company Hocoma [7]. Andago is targeted towards helping patients having neurological damage such as strokes and SCIs as they need further assistance and therapy.

Patient is secured with the BWS system attached firmly overhead to the mobile robot base. The man-machine interaction during therapy session leads to a condition where either therapist or the robot itself can change the condition by altering control parameters through the progress [8]. This device essentially equips the patient with an independent gait assistance. It is certainly a state of the art implementation of robotics into clinical practice.

In a case study, a female stroke patient producing initiated step for only 50% during her first four therapy session [9]. Following three weeks, the clinical observation validates that she has able to walk independently and has pass through her difficulties and ailments with success.

Figure 2: Andago [6]

2.1.3. KineAssist

The KineAssist (Figure 3) consists of an omnidirectional base, harness joining at the pelvic, force-torque (FT) sensor that acts for the admittance controller, and an active BWS [10]. The robot provides stability of the unloading body-weight and allows the pelvic movement without any restriction. The mobile base is omnidirectional; equipped with forward-backward, lateral as well as rotational movement during its operation. Stroke patients usually overuse their pelvic movements and tend to have abnormal walking behavior as well as to avoid them from falling down.

Figure 3: KineAssist [11]